

Marine Mammal Acoustic Tracking from Adapting HARP Technologies

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LONG-TERM GOALS

The long-term goal of this project is to track swimming and diving marine mammals using their sounds recorded by a single autonomous acoustic recorder. These tracks will provide details of animal movement which can be used to develop baseline and acoustic stimuli (e.g. anthropogenic noise) models.

OBJECTIVES

Large aperture acoustic arrays with sensors separated by a few km's have been used to localize and track large cetacean such as baleen and sperm whales (e.g. McDonald et al., 1995; Tiemann et al., 2004; Nosal and Frazer, 2007). However, these arrays are often stationary, can be expensive to deploy and maintain, and they are not well-suited to track higher frequency, more directional signals from small odontocetes (i.e. echolocation clicks).

The technical objective of this effort is to record echolocation clicks from odontocetes using multiple hydrophone sensors in a small aperture array to provide 3-dimensional bearing angles to these animals from a single autonomous acoustic recorder.

APPROACH

Our approach for the small aperture array is to use four broad-band hydrophones arranged in a tetrahedron with sensor separations of many wavelengths in the odontocete echolocation frequency range (10's of kHz). The array is rigidly attached about 3m above a seafloor-mounted frame. Besides providing fixed-array geometry, deploying the instrument on the seafloor provides good geometry for tracking animals echolocating downward and at depth, such as foraging beaked whales, and for animals clicking near the sea surface such as dolphins.

Time synchronization of small aperture array sensor data is critical to calculating accurate bearing angles. Our technical approach is to modify a single-channel High-frequency Acoustic Recording

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Package (HARP – Wiggins and Hildebrand, 2007) to include a four-channel, high-speed Analog-to-Digital Converter (ADC) to provide synchronization of the multi-channel data from a single clock.

When a toothed-whale emits a click in the direction of the array, it will arrive at different times at the four sensors. The Time Difference of Arrivals (TDOAs) between the six fixed sensor pairs (i.e., 1-2, 1-3, 1-4, 2-3, 2-4, 3-4) can be used to calculate a 3-dimensional bearing angle to the sound source. Collecting successive bearing angle will provide tracking of the sound source providing swimming and diving information on echolocating odontocetes.

WORK COMPLETED

HARP Modifications

We developed a four-channel ADC card to work with existing HARP electronics. HARP firmware was modified to record the four digitized signals at a rate of 100 kSamples/sec per channel on to a set of hard disk drives (~2 TB). Standard HARP hydrophones, modified to provide an effective bandwidth of approximately 2 kHz – 50 kHz, were mounted into a tetrahedron array, and the array was mounted to a HARP frame. Sensor spacing was about 0.4m – 0.6m or approximately 300 – 400 usec TDOA for a signal along the axis of a sensor pair.

Field Work

We deployed one four-channel Tracking HARP on the west side of San Nicolas Basin offshore of southern California in a known beaked whale foraging area on the seafloor at about 1000m deep. The instrument continuously recorded four channels at 100 kSamples/sec until the disks drives were full (about one month). The instrument was acoustically navigated to within a few meters using the R/V Sproul configured with GPS and acoustic ranging equipment. The navigation procedure also provided acoustic data that was used to orientate the direction and tilt of the hydrophone array.

Data Processing

The Triton software package developed to allow processing, analysis and evaluation of HARP data (Wiggins and Hildebrand, 2007) was modified to work with multi-channel data including computing Long-Term Spectral Averages (LTSAs) to find events of interest in long duration acoustic data sets. After finding events of interest (i.e., bouts of echolocation sounds), cross-correlating signals between sensor pairs or picking signal first arrivals from the time series waveforms provides TDOAs which allows estimation of 3-dimensional bearings.

Future Work

In November 2010, we will re-visit the beaked whale site on the west side of San Nicolas Basin to deploy two four-channel Tracking HARPs with the goal of collecting an additional data set that will allow cross-fixing the two instruments 3-dimensional bearing angles to provide 3-dimensional location tracks for foraging beaked whales.

RESULTS

Numerous beaked whale foraging bouts were recorded by the Tracking HARP. Using about 6000 beaked whale detections during a single foraging bout, azimuth and elevation angle time series clearly show diving and swimming behavior, and time-correlated received sound level variability may indicate animal heading direction (Fig. 1). The top two plots show the ‘red’ animal starts echolocating while diving about 10 minutes before the ‘blue’ animal’s diving echolocation starts, and the animals coming

together azimuthally over time. The received level rise and fall patterns over time (bottom plot) may be related to beam angle heading (i.e., direction) of echolocating animals.

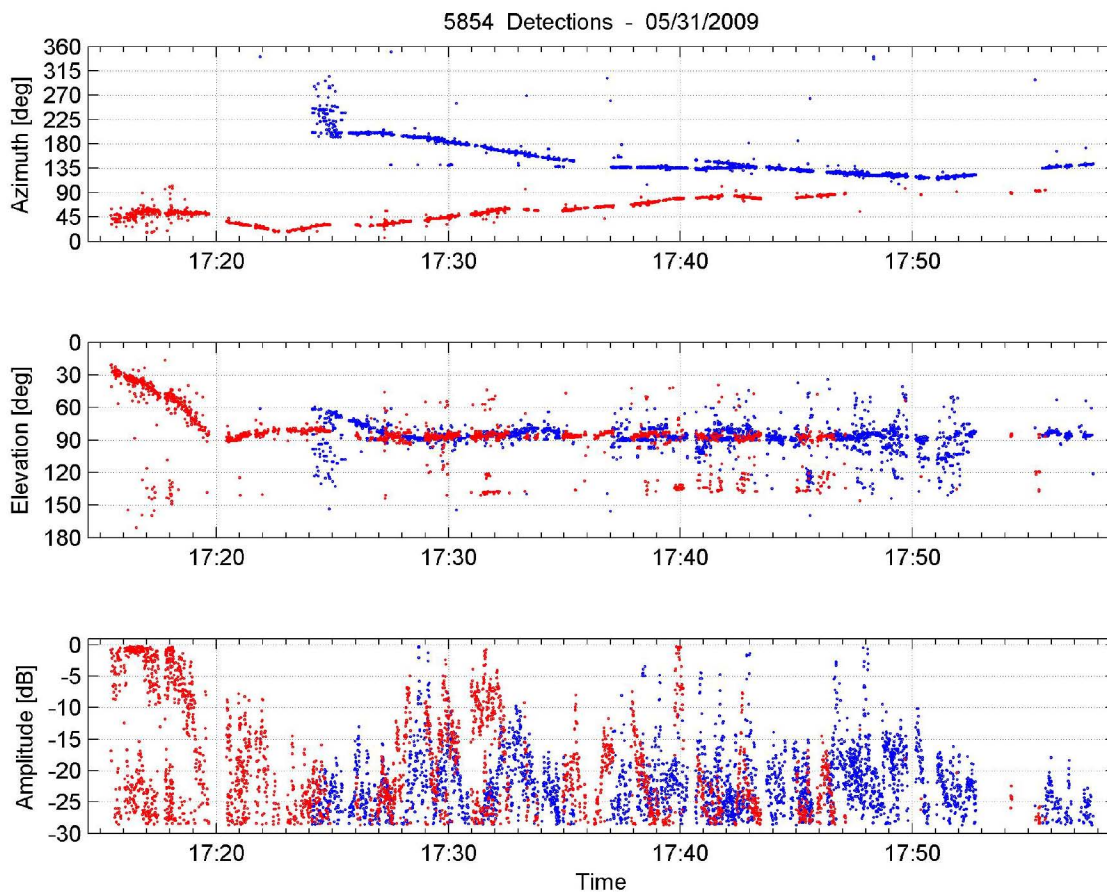


Figure 1. Two echolocating beaked whale azimuth (top) and elevation (middle) angles and received amplitudes (bottom) from a 43 minute foraging bout recorded by the Tracking HARP.

Dolphins (presumably *Delphinus sp.*) were also recorded by the Tracking HARP. From one echolocation bout, approximately 60,000 dolphin clicks were detected and used to calculate 3-dimensional angles. Assuming the animals were at or near the sea surface, dolphin locations can be estimated over time providing a track of the group (Fig. 2).

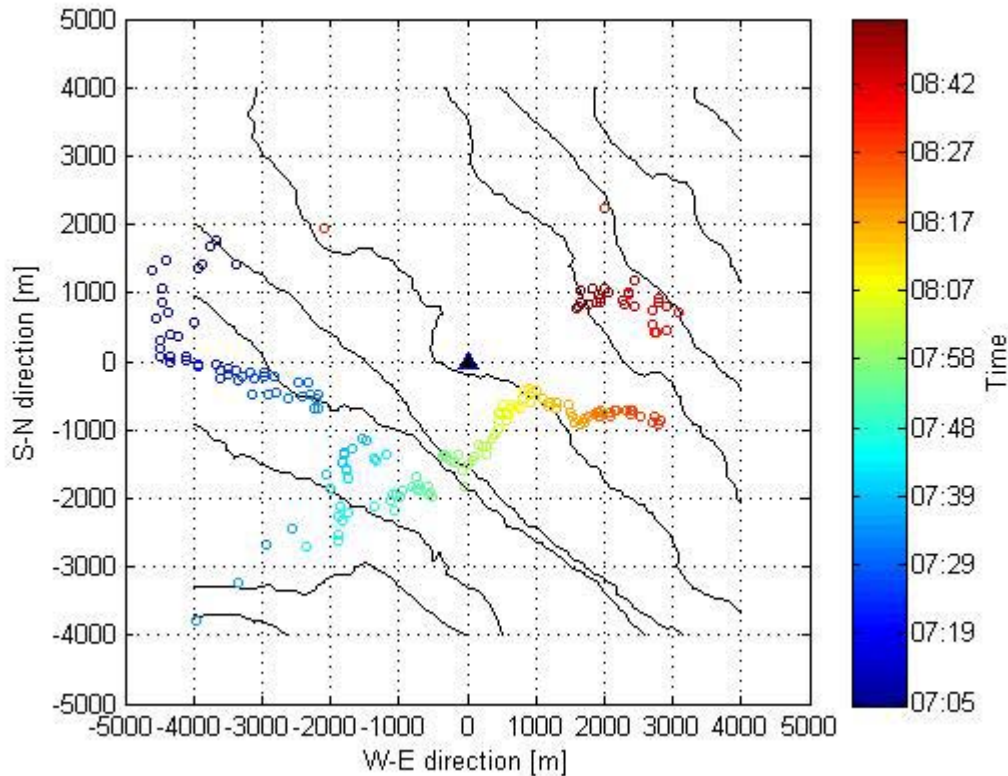


Figure 2. Plan view map of a dolphin group track. Circles are averaged group location with color showing time. The triangle shows the four-channel Tracking HARP location near the 1000m contour. Other contours are separated by 100m with deeper ones to the upper right and shallower to lower left.

IMPACT/APPLICATIONS

Data from a single Tracking HARP provides valuable information on diving and presumably foraging behavior of beaked whales from numerous dives over long periods without needing additional instruments or costly cabled seafloor arrays – or difficult to attached tag devices . In addition to using these recordings to obtain 3-dimensional angles to deep diving whales, the clicks and whistles of passing dolphins can be tracked. By monitoring these animals with this technique, baseline swimming and diving models can be developed and compared to recordings with anthropogenic noise sources. Also, localizations will allow us to estimate detection range for these various species using seafloor acoustic recorders which in turn can be used for population abundance estimations.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for the development of HARP instrumentation and collection of the acoustic data processed for beaked whales with ONR support during N000140910489.

Project title: SBIR Topic N07-024 Marine Mammal Acoustics; awarded to Sonalysts; Sponsor: NavAir PMA264; Support from this project has allowed development of two prototype small aperture array instruments and analysis of data recorded by these instruments in a known beaked whale habitat.

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